

**U.S. DEPARTMENT OF ENERGY**  
**FEDERAL ASSISTANCE PROGRAM/PROJECT STATUS REPORT**  
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<b>8. Performance Variances, Accomplishments, or Problems</b>  The project is proceeding according to the proposed schedule and budget. Refer to the attached document for a discussion on the project status and accomplishments.  <div style="border: 1px solid black; height: 15px; width: 100%; margin-top: 5px;"><input type="checkbox"/> None</div>		
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# MERCURY CONTROL TECHNOLOGIES FOR UTILITIES BURNING LIGNITE COAL

Quarterly Report

*For the period of April 1 – June 30, 2002*

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## **MERCURY CONTROL TECHNOLOGIES FOR UTILITIES BURNING LIGNITE COAL**

### **SUMMARY**

The Energy & Environmental Research Center (EERC) is conducting research for the first phase of a 3-year, two-phase consortium project to develop and demonstrate mercury control technologies for utilities that burn lignite coal. The overall intent of the project is to help maintain the viability of lignite-fired energy production by providing local utilities with low-cost options for meeting future mercury regulations. Phase I objectives are to develop a better understanding of mercury interactions with flue gas constituents, test a range of sorbent-based technologies targeted at removal of  $\text{Hg}^0$  (elemental mercury) from flue gases, and demonstrate the effectiveness of the most promising technologies at the pilot scale. The Phase II objective is to demonstrate and quantify sorbent technology effectiveness, performance, and cost at a sponsor-owned/operated power plant. Phase I results obtained during the quarterly period of April 1 through June 30, 2002, are presented in this report. Note, observations and results presented in this quarterly report should be viewed as preliminary. A report containing final conclusions will be issued at the end of the project.

Phase I has two primary tasks. Task 1 activities are focused on performing bench-scale tests to screen a number of potential sorbents. Task 2 activities are focused on performing pilot-scale tests to evaluate sorbent effectiveness under a number of different possible control configurations and operating conditions. During this reporting period, most of the effort focused on bench-scale testing. The bench-scale work focused primarily on identifying and selecting high-sodium lignites to produce activated carbons, activation and preparation of a number of carbon-based sorbents, and testing sorbents in a fixed-bed reactor for their ability to capture  $\text{Hg}^0$ . In addition to the activated carbon sorbents, a calcium silicate sorbent obtained from Arcadis was tested.

The results of the fixed-bed testing under simulated lignite combustion flue gas composition for activated carbons (prepared at  $750^\circ\text{C}$  and commercially available) showed some initial breakthrough followed by increased mercury capture up to about 3 hours. After 3 hours, the released mercury was primarily in an oxidized form ( $>90\%$ ). The reason for the initial breakthrough of mercury during the first 30–40 minutes of testing is not clearly understood. This does not occur when the flue gases contain higher levels of acid gases. Under bench-scale test conditions, the unactivated sorbents and calcium silicate were ineffective at capturing mercury.

The results of the prepared carbons activated at  $800^\circ\text{C}$  and the commercial carbon show better mercury capture and high conversion of elemental to oxidized mercury ( $>95\%$ ) than the carbons activated at  $750^\circ\text{C}$ . The initial breakthrough was not as significant in this case.

Additional tests were conducted in the baseline flue gas at higher levels of  $\text{HCl}$ ,  $\text{SO}_2$ , and  $\text{NO}$  for the Luscar coal carbon activated at  $800^\circ\text{C}$  and the NORIT flue gas desulfurization (FGD) carbon. The Luscar coal activated carbon showed less breakthrough after 1.5 hours as compared to the NORIT FGD. The activated carbons showed no initial breakthrough.

Results of the bench-scale fixed-bed screening suggest that steam-activated carbons produced from any of the received lignites could produce comparable mercury sorbents. Sorbents activated at 800°C were more effective at mercury capture than those activated at 750°C. Comparison of activated versus unactivated chars indicates that activation is a necessary step as the unactivated chars exhibited immediate breakthrough of  $\text{Hg}^0$ . Most of the carbon-based sorbents tested exhibited an initial  $\text{Hg}^0$  breakthrough that diminished rather quickly over time. This observed phenomena was hypothesized as a conditioning period. This conditioning appeared in all samples exposed to the low chlorine (1 ppm) simulated flue gas, leading to the conclusion that conditioning during that period is associated with the HCl content of the flue gas. One half hour of simulated flue gas exposure with low HCl content was required to reach the level of activation necessary for mercury capture.

The sorbents that showed promise in capturing and retaining  $\text{Hg}^0$  were selected for pilot-scale testing. The selection criteria for the sorbents included reactivity (as compared to baseline NORIT FGD), capacity, physical properties (particle size, surface area, functionality), and cost (relative to NORIT FGD carbon [50 cents/lb]). Based on this criteria and discussion with the project sponsors, the NORIT FGD and Luscar char-derived sorbents were selected for further pilot-scale testing. Two weeks of pilot-scale testing were done during the last 2 weeks of the reporting period. Results from these tests will be discussed in the next quarterly report.

Completion of project activities are on schedule and within budget. A more detailed description of project results and accomplishments during this reporting period is as follows.

## **PROJECT DESCRIPTION**

Based on health, emissions, and scientific data, the U.S. Environmental Protection Agency and the Canadian Council of the Ministries of Environment have determined that mercury emitted from utility power plants should be reduced. U.S. and Canadian power plants burning lignite have shown higher  $\text{Hg}^0$  emissions than plants burning bituminous coals. This form of mercury is much more difficult to remove and requires an innovative approach.

The EERC is conducting tests for Phase I of a 3-year, two-phase consortium project to develop and demonstrate mercury control technologies for utilities that burn lignite coal. The overall intent of this project is to help maintain the viability of lignite-fired energy production by providing local utilities with low-cost options for meeting future mercury regulations. Phase I objectives are to develop a better understanding of mercury interactions with flue gas constituents, test a range of sorbent-based technologies targeted at removal of  $\text{Hg}^0$  from flue gases, and demonstrate the effectiveness of the most promising technologies at the pilot scale. The Phase II objective is to demonstrate and quantify sorbent technology effectiveness, performance, and cost at a sponsor-owned/operated power plant.

## GOAL AND OBJECTIVES

The overall goal of the project is to develop and demonstrate mercury control technologies for utilities that burn lignite coal. The specific objectives designed to meet the goal of the project include:

- Developing a better scientific understanding of mercury interactions with flue gas constituents which will lead to the development and demonstration of effective control technologies in lignite-fired systems.
- Testing a range of sorbent-based technology options that target oxidation and removal of  $\text{Hg}^0$  from power plant flue gases.
- Demonstrating the ability of sorbent-based technologies to capture mercury in pilot-scale facilities.
- Selecting the most promising technology for Phase II demonstration and quantification of sorbent technology effectiveness, performance, and cost at a SaskPower power plant.

## APPROACH

The project focus is on testing and demonstrating effective sorbents for mercury control from electrical power plants firing lignite coal. Preliminary data from both laboratory and field tests indicate that both oxidation and removal can be achieved by injecting finely dispersed solid catalytic sorbents that can be removed in an electrostatic precipitator (ESP) or fabric filter (FF). Sorbent preparation (i.e., grinding) and production to a small and narrow size range and good dispersion into the flue gas serve to promote a high level of diffusional mass transfer from the bulk flue gas to the particle surfaces. Competing reactions with the gas species commonly found in flue gas, including  $\text{SO}_2$ ,  $\text{NO}_x$ ,  $\text{HCl}$ , and water vapor, have been found to be immensely important and must be considered during sorbent performance tests. A combination of  $\text{SO}_2$  and  $\text{NO}_2$  (even small amounts) has been found to reduce the effective capacity of sorbents tested in a laboratory thin-bed reactor, apparently because of the possible formation and desorption of mercury nitrate hydrate. Several different avenues of research can be pursued to improve mercury conversion and collection via sorbent technology by addressing improvements in dispersion, diffusion, surface chemistry of sorbent materials, sorbent utilization, optimization of operating conditions, and addition of sorbent contactor collectors.

Based on interest expressed by project sponsors, the work plan is focused primarily on the development, testing, and demonstration of sorbent injection technologies in combination with particulate removal devices (ESPs and FFs) for effective mercury removal. Phase I efforts include bench- and pilot-scale testing to explore and identify sorbents, operating conditions, and combinations of particulate control devices which show promise for full-scale application. Phase II activities will focus on the demonstration of the most promising sorbent technology at a lignite-fired SaskPower power plant. This quarterly report summarizes the accomplishments and results obtained during the reporting period of April 1 through June 30, 2002.



## RESULTS AND DISCUSSION

### Bench-Scale Results

The bench-scale work focused primarily on identifying and selecting high-sodium lignites to produce activated carbons, preparation of sorbents, and testing sorbents in a fixed-bed reactor for their ability to capture  $\text{Hg}^0$ . In addition to the activated carbon sorbents, a calcium silicate sorbent obtained from Arcadis was tested.

Activated carbon sorbents were prepared from Luscar coal, Luscar char, Center coal, and Beulah–Zap coal. The coals were air-dried, ground, and sieved. Particles of 1-mm diameter (–8 +20 mesh) were used in the preparation of the char. For carbonization, 150 g of the granular coal (–8 +20 mesh) were placed in a quartz tube reactor and heated to 400°C in a gentle flow of nitrogen. The reactor was held at this temperature until tarry material ceased to evolve. The char produced was stored under nitrogen until steam activated.

For steam activation, each char was placed in a vertical steel tube reactor. The tube reactor was heated to 750° or 800°C in a gentle flow of nitrogen. Once the temperature was attained, steam was introduced into the bottom of the reactor at the rate of 65 cm<sup>3</sup>/min and a temperature of 450°C. The char was maintained at temperature in a gentle flow of steam and nitrogen for 30 minutes. At the end of the activation process, the steam was stopped, and the reactor was cooled to room temperature in flowing nitrogen. The activated carbon was removed from the reactor, weighed, and stored under nitrogen for further use. The yields of char and carbon produced under these conditions are listed in Table 1.

**Table 1. Char and Carbon Yields**

	Activation Conditions	Ratio of Char to Coal	Ratio of Carbon to Coal	Ratio of Carbon to Char
Luscar Coal	Carbonized @400°C, steam Activation @750°C/30 min	0.481	0.367	0.764
Luscar Coal	Carbonized @400°C, steam Activation @800°C/30 min	0.493	0.356	0.722
Luscar Char	Steam activation @750°C/30 min	NA	NA	0.647
Luscar Char	Steam activation @800°C/30 min	NA	NA	0.576
Beulah–Zap Coal	Carbonized @400°C, steam Activation @750°C/30 min	0.510	0.370	0.726
Center Coal	Carbonized @400°C, steam Activation @750°C/30 min	0.496	0.360	0.725
Center Coal	Carbonized @400°C, steam Activation @800°C/30 min	0.521	0.346	0.665

The surface area of the produced activated carbons was determined by iodine numbers to investigate the influence of coal type as well as char preparation and activation conditions used to produce the activated carbon. Prepared activated carbons were ground to pass through a 200-mesh sieve and tested using American Society for Testing and Materials (ASTM) Procedure

D4607. The results, given in Table 2, indicate that the commercial sorbent has the highest surface area at 524.8  $\mu\text{g I}_2/\text{g}$ . The carbons from the Luscar coal and char had roughly 20% less surface area, and the carbons from the other coals averaged 36% less surface area. In all cases, the carbon activated at 800°C had less surface area than the same carbon activated at 750°C.

**Table 2. ASTM Procedure D4607 Results**

	Activation Conditions	Iodine No.
Luscar Coal	Steam activation @750°C/30 min	424.3
Luscar Coal	Steam activation @800°C/30 min	398.1
Luscar Coal	Steam activation @750°C/30 min	439.6
Luscar Coal	Steam activation @800°C/30 min	427.4
Beulah–Zap Coal	Steam activation @750°C/30 min	331.5
Center Coal	Steam activation @750°C/30 min	352.8
Center Coal	Steam activation @800°C/30 min	321.5
NORIT FGD	Unknown	524.8

The activated carbons were ground to pass through a 400-mesh sieve for testing in the bench-scale mercury sorption screening tests. These screening measurements were used to evaluate mercury capture effectiveness, oxidation potential, and capacity for the selected sorbents. Eighteen fixed-bed tests were completed on commercially available and EERC-prepared sorbents. The fixed-bed tests were performed at two sets of flue gas conditions. The first simulated flue gas composition was based on flue gas measurements made at lignite-fired power plants and the chlorine content of lignite coals. Chlorine analysis of the coals is listed in Table 3. The first simulated flue gas consists of the following components: 6% O<sub>2</sub>, 12% CO<sub>2</sub>, 15% H<sub>2</sub>O, 580 ppm SO<sub>2</sub>, 120 ppm NO, 6 ppm NO<sub>2</sub>, and 1 ppm HCl in N<sub>2</sub>. The second simulated flue gas composition was the baseline test flue gas composition used in past testing. The flue gas components were as follows: 6% O<sub>2</sub>, 12% CO<sub>2</sub>, 8% H<sub>2</sub>O, 1600 ppm SO<sub>2</sub>, 400 ppm NO, 20 ppm NO<sub>2</sub>, and 50 ppm HCl in N<sub>2</sub>. The mercury sorption tests conducted under the second set of conditions allowed for comparison to past testing.

**Table 3. Chlorine Analysis**

Sample	Chlorine, $\mu\text{g/g}$
Luscar Coal	18.0
Beulah–Zap Coal	12.6
Center Coal	14.3

Table 4 describes the sorbents tested in the bench-scale screening process, including activation temperatures and conditions under which each was tested. The test protocol is to analyze total mercury at the outlet until mercury breakthrough reaches a steady state (usually between 6 and 7 hours into the run). At that point, the instrument is switched to analyze the Hg<sup>0</sup> level at the outlet followed by the Hg<sup>0</sup> level at the inlet before the test is terminated. The following figures show the changes in mercury at the outlet as percent of mercury input into the

**Table 4. Bench-Scale Sorbents**

Material	Activation (Temp., °C)	Flue Gas Conditions	
		Lignite	Baseline
Beulah–Zap Lignite Coal	Yes (750)	X	
Center Lignite Coal	Yes (750)	X	
Center Lignite Coal	Yes (800)	X	
Luscar Lignite Coal	Yes (750)	X	X
Luscar Lignite Coal	Yes (800)	X	
Luscar Char	Yes (750)	X	
Luscar Char	Yes (800)	X	
Luscar Char	No	X	
Luscar Char Dust	No	X	
NORIT FGD	Yes (unknown)	X	X
Calcium Oxide	No	X	

system as a function of time. Figure 1 shows the results of the fixed-bed tests under simulated lignite flue gas for activated carbons (prepared at 750°C and commercially available), unactivated sorbents, and the oxidized calcium silicate sorbent. The activated carbons showed some initial breakthrough followed by increased mercury capture up to about 3 hours. After 3 hours, breakthrough or release of mercury and the released mercury was primarily in an oxidized form (>90%). The reason for the initial breakthrough of mercury during the first 30 to 40 minutes of testing is not clearly understood. This does not occur when the flue gases contain higher levels of acid gases. The unactivated sorbents and calcium silicate were ineffective at capturing mercury (an estimate of conversion was not determined), and the tests were discontinued after 2 to 4 hours.

Figure 2 shows the results of the prepared carbons activated at 800°C and the commercial carbon under the same simulated lignite gas conditions as shown in Figure 1. The data show better mercury capture than the carbons activated at 750°C and high conversion of elemental to oxidized mercury (>95%). The initial breakthrough was not as significant in this case. The same NORIT FGD carbon test run is plotted in both figures to assist in the visual comparison of the data.

In order to compare these results with the database of past tests, the Luscar coal carbon activated at 800°C and the NORIT FGD carbon were tested under a second flue gas composition (referred to as baseline). The primary differences in flue gas components were the higher levels of HCl, SO<sub>2</sub>, and NO<sub>x</sub>. Figure 3 shows the results of the testing performed under the higher chlorine content bench-scale testing conditions (only total mercury at the outlet is included in the graph). NORIT FGD was tested under both conditions, providing a commercial comparison to all other sorbents and a reference to compare these results to other tests performed on the bench-scale unit. These tests yielded better mercury capture initially and earlier breakthrough. The Luscar coal activated carbon showed less breakthrough after 1.5 hours as compared to the NORIT FGD. These activated carbons also showed no initial breakthrough.

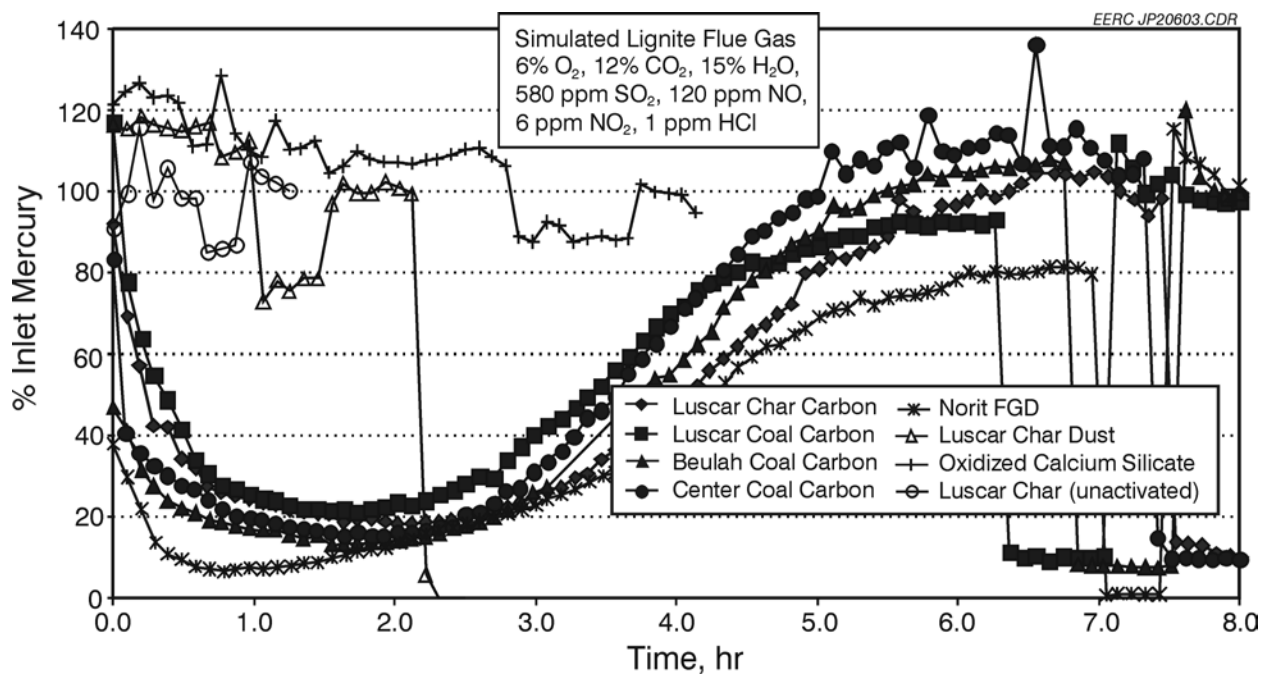


Figure 1. Bench-scale fixed-bed results under simulated lignite flue gas for carbons prepared at 750°C.

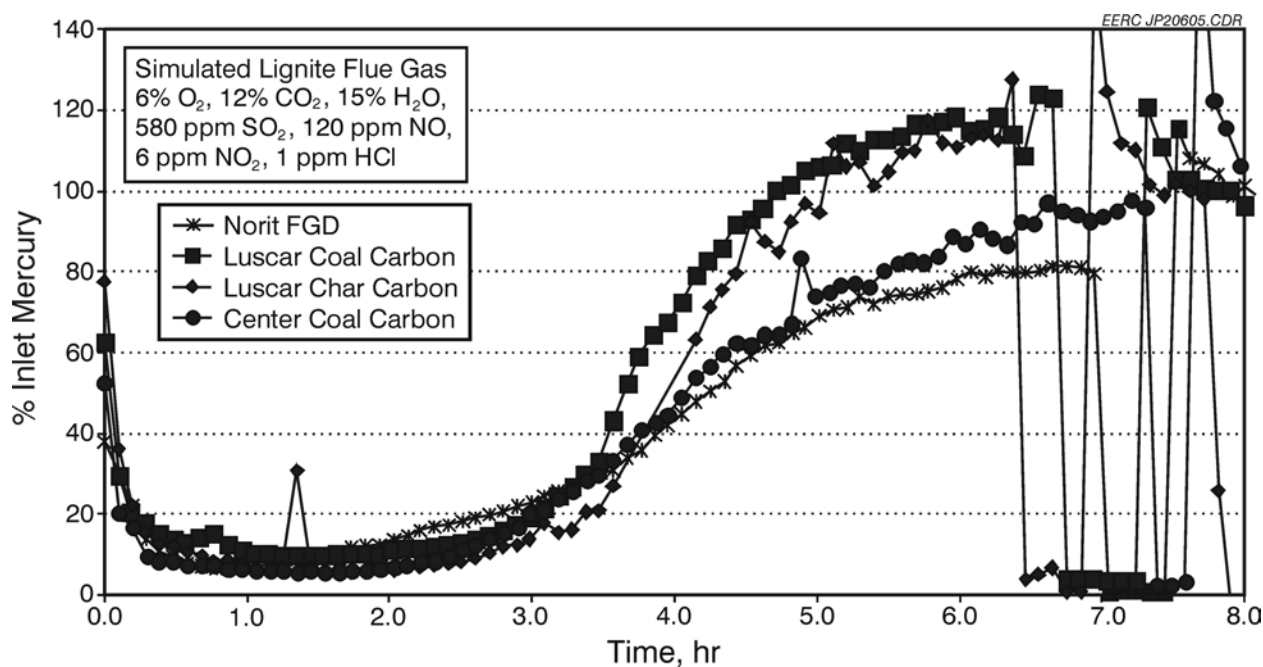


Figure 2. Bench-scale fixed-bed results under simulated lignite flue gas for carbons prepared at 800°C.

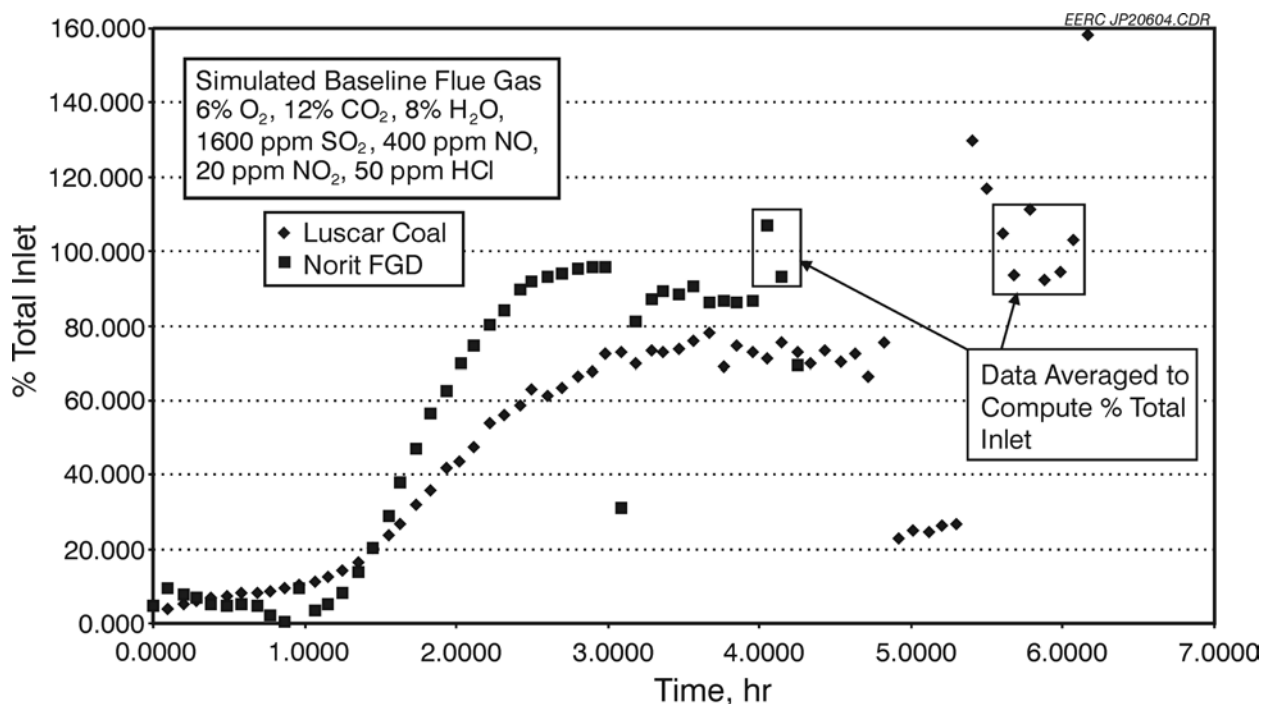


Figure 3. Bench-scale fixed-bed results under simulated baseline flue gas for Luscar coal activated at 800°C and NORIT FGD.

Concurrent with the bench-scale screening, coals were analyzed for proximate–ultimate (Tables 5 and 6) and bulk ash analyses (Table 7). The coals contained between 41% and 44% volatile matter while the volatile matter content of the char was reduced to 24% on a moisture-free basis during the commercial charring process. Likewise, the fixed carbon content of the char was much higher (71%) than in the coals (around 50%). Percentage of sodium oxide ranged from 4.8% to 9.9% by weight for the North Dakota lignites, whereas the NORIT FGD activated carbon contained less than 1% sodium oxide.

The screening data were assembled and reviewed by the project sponsors who recommended inclusion of Luscar char activated at 800°C for the pilot-scale tests. The decision was based on four factors: better-to-similar performance compared to other sorbents, better mercury capture at higher activation temperatures, potential for economic production, and the convenience of having ready-made char available from one of the sponsors.

Preparation of the Luscar char-derived sorbent proved to be more challenging than originally thought. Preparation followed three paths using the Luscar char: activation in a 10-lb integrated bench-scale gasifier (IBG), in a 1.5-inch tube reactor, and in a 1-inch tube reactor. The as-received char was sieved, and particles between –8 and –20 mesh were collected for activation. A measured amount of this size of char was placed in each reactor, the temperature of the char was recorded by placing a thermocouple in the middle of the char bed, and the char was heated at 800°C in steam for 30 minutes.

**Table 5. Proximate Analyses, %**

	Luscar Coal		Luscar Coal Char		Antelope/Beulah–Zap Coal		Center Coal	
	AR*	MF**	AR	MF	AR	MF	AR	MF
Moisture	32.5		7.8		28.3		23.3	
Volatile Matter	27.76	41.12	22.35	24.25	31.62	44.09	33.04	43.1
Fixed Carbon	26.48	48.83	54.84	71.03	30.77	49.34	34.74	51.23
Ash	13.26	19.64	15.01	16.29	9.3	12.97	8.92	11.63

\* As received.

\*\* Moisture free.

**Table 6. Ultimate Analyses, %**

Sample	Luscar Coal		Luscar Coal Char		Antelope/Beulah–Zap Coal		Center Coal	
	AR*	MF**	AR	MF	AR	MF	AR	MF
Hydrogen	6.45	4.21	3.35	2.69	6.05	4.06	5.61	3.94
Carbon	43.82	64.91	60.9	66.08	44.94	62.66	45.93	59.91
Nitrogen	0.82	1.22	1.12	1.21	0.83	1.16	0.84	1.09
Sulfur	0.61	0.9	0.8	0.87	0.6	0.84	0.99	1.29
Oxygen (ind.)	35.03	9.21	18.82	12.86	38.27	18.31	37.72	22.14
Ash	13.26	19.64	15.01	16.29	9.3	12.97	8.92	11.63

\* As received.

\*\* Moisture free.

**Table 7. Bulk Ash Analyses, wt%**

Sample	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	CaO	MgO	Na <sub>2</sub> O	K <sub>2</sub> O	SO <sub>3</sub>
Luscar Coal	38.3	15.2	6.0	0.6	0.2	15.5	3.5	8.7	1.4	10.6
Luscar Coal Char	32.9	17.3	6.4	0.6	0.2	16.4	3.8	9.9	0.6	12.0
Antelope/Beulah–Zap Coal	36.6	13.6	8.1	0.5	0.2	18.1	5.8	5.8	1.1	10.3
Center Coal	43.8	14.3	7.6	0.5	0.1	11.6	4.5	4.3	2.0	11.2
NORIT FGD	38.5	15.6	10.6	1.3	0.0	18.1	4.7	0.7	0.6	10.0

For the IBG activation process, 4.5 kg of char was placed in a kiln reactor and heated to 800°C in N<sub>2</sub> flow. Once the internal temperature of the char reached 800°C, a 50/50 mixture of N<sub>2</sub> and steam was introduced. Water was converted to steam at a rate of 60 g/min by a superheater before introduction into the reactor. The temperature tended to drop with contact from the steam. Once it reached 750°C, steam flow was cut to allow the temperature to climb back to 800°C. Total contact time for steam and char was 30 minutes.

A second, larger stainless steel reactor (1.5-inch ID) was fabricated and used for steam activation. However with this reactor, it was not possible to attain the desired activation temperature. This could be a result of heat loss from the heavy connectors used in this reactor. This method was abandoned in favor of the 1-inch reactor used to create the initial screening carbons.

For steam activation, 95 g of the char (-8 +20 mesh) was placed in a vertical stainless steel tube reactor. The tube reactor was heated to 800°C in a gentle flow of nitrogen. At this stage, steam was introduced from the bottom of the reactor. The char was then heated at 800°C in a gentle flow of steam and nitrogen for 30 minutes. The moist nitrogen flow was stopped after 30 minutes, and the reactor was cooled slightly before removal from the furnace. The reactor was allowed to cool to room temperature. The activated carbon was removed from the reactor, weighed, and stored under nitrogen for further use. This process produced 5.3 kg of activated carbon for the pilot-scale testing with a mean 70% yield by mass produced under these conditions. This process was repeated until a sufficient quantity of sorbent was available for pilot-scale testing.

### **Pilot-Scale Results**

Results from bench-scale testing were presented to project sponsors during a conference call on May 21. Minutes from this meeting were prepared and sent to each sponsor representative. The sorbents that showed promise in capturing and retaining Hg<sup>0</sup> were selected for pilot-scale testing in the EERC particulate test combustor (PTC). The selection criteria for the sorbents included reactivity (as compared to baseline NORIT FGD), capacity, physical properties (particle size, surface area, functionality), and cost (relative to FGD carbon [50 cents/lb]). Based on this criteria and discussion with the project sponsors, the NORIT FGD and Luscar char-derived sorbents were selected for further pilot-scale testing. Test conditions and equipment configurations were discussed and agreed on during the conference call. The basic test configurations include tests with an ESP only, an ESP followed by a baghouse, a baghouse, and the EERC Advanced Hybrid<sup>TM</sup>. A diagram of a PTC equipped with an ESP followed by a baghouse is included in Figure 4. Based on discussion during the conference call, a detailed test matrix was decided on and is included in Table 8. The first 2 weeks of testing were completed in the last 2 weeks of June. Results of these tests and other pilot-scale tests will be discussed in the next quarterly report.

### **PROJECT SCHEDULE AND BUDGET**

The project is scheduled for a 2½- to 3-year period, with Phase I activities expected to be completed within 12 months and Phase II activities following for another 24 months. Table 9 shows the project time line and the estimated level of completion for each of the tasks under Phase I. Project-related activities are being completed on time as compared to the original project schedule. Likewise, the amount spent on each proposed activity is close to what was originally budgeted. Consequently, at this stage, the project is on schedule and within budget.

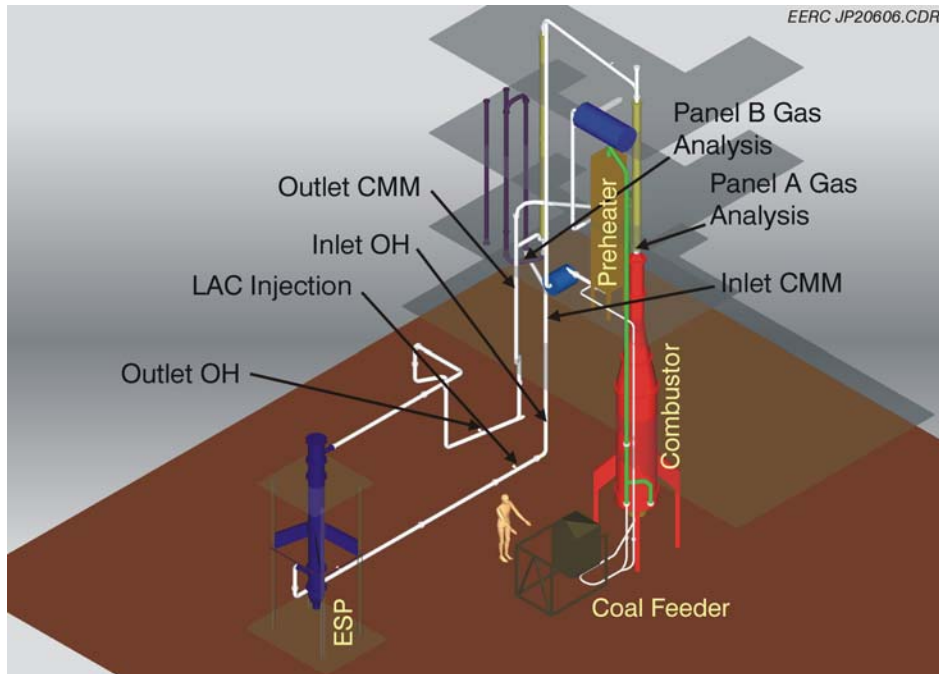


Figure 4. PTC equipped with ESP and baghouse.



**Table 8. Test and Operations Schedule**

Test Period Week 1, June 17–21												
Test No.	T1 Base	T2	T3	T4 <sup>A</sup>	T5	T6	T7	T8	T9	T10	T11	T12
Test Duration, hr	Average 2 to 3 tests per 24 hour period depending on conditions and CMM information/steady state.											Contingency Test, Repeat, or Other
Coal	C1 <sup>B</sup>	C1	C1	C1	C1	C1	C1	C1	C1	C1	C1	
Hardware	ESP	ESP	ESP	ESP	ESP	ESP	ESP	ESP	ESP	ESP	ESP	
Temp., °F	300	300	300	300	300	300	300	300	400	400	400	
Sorbent	None	S2 <sup>C</sup>	S2	None	S1 <sup>D</sup>	S1	S1	S1	S1	None	S1	
Sorbent Size	N.A.	A.R. <sup>E</sup>	A.R.	N.A.	A.R.	A.R.	A.R.	Fine	A.R.	N.A.	Fine	
Sorbent:Hg Ratio	0	5000 <sup>F</sup>	10,000 <sup>F</sup>	0	T2 Ratio	T3 Ratio	30,000 <sup>F</sup>	T2 Ratio	T3 Ratio	0	T2 Ratio	
Sorbent Inject., grams/hr	0	20.4 <sup>F</sup>	40.9 <sup>F</sup>	0	T2 Rate	T3 Rate	122.6 <sup>F</sup>	T2 Rate	T3 Rate	0	T2 Rate	
Flue Gas Flow Rate	132 scfm											
FG O <sub>2</sub> Conc. (vol. %, dry)	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	
Sampling												
Ontario Hydro	Minimum of 1 per day at the inlet and minimum of one per test at the outlet except for those that are between runs.											
CMM	Continuous inlet and outlet during day and outlet only at night.											
Solids	One set of coal, sorbent, and ash samples for each test.											

<sup>A</sup> Between runs, conditions will be returned to baseline based on CMM mercury measurements only.

<sup>B</sup> C1 = Luscar coal from Poplar.

<sup>C</sup> S2 = NORIT FGD, lignite-based activated carbon.

<sup>D</sup> S1 = Luscar char, steam activated.

<sup>E</sup> A.R. = as received.

<sup>F</sup> Actual sorbent flow rates to be determined based on percent removals from CMM data for tests T2, T3, & T7. T2 flow = 50%, T3 flow = 70%, and T7 = 90% removal or 30,000:1 ratio, whichever comes first (same applies to tests T14 and T15 at removal targets of 70% and 90%, respectively).

Continued . . .

**Table 8 (continued)**

Test Period Week 2, June 24–28													
Test No.	T13	T14	T15	T16	T17 <sup>A</sup>	T18	T19	T20	T21	T22	T23	T24 <sup>A</sup>	T25
Test Duration, hr	Average 2 to 3 tests per 24 hours depending on conditions and CMM information/steady state.												
Coal	C1 <sup>B</sup>	C1	C1	C1	C1	C1	C1	C1	C1	C1	C1	C1	Contingency Test, Repeat, or Other
Hardware	ESP/FF	ESP/FF	ESP/FF	ESP/FF	ESP/FF	ESP/FF	ESP/FF	ESP/FF	ESP/FF	ESP/FF	ESP/FF	ESP/FF	
Temp., °F	300	300	300	300	300	300	400	400	400	400	400	400	
Sorbent	None	S1 <sup>C</sup>	S1	S1	None	S2 <sup>D</sup>	None	S1	S1	S2	S2	None	
Sorbent Size	N.A.	A.R. <sup>E</sup>	A.R.	Fine	N.A.	A.R.	N.A.	Fine	A.R.	Fine	A.R.	N.A.	
Sorbent:Hg Ratio	0	2000 <sup>F</sup>	5000 <sup>F</sup>	T14 Ratio	0	T15 Ratio	0	T14 Ratio	T15 Ratio	T14 Ratio	T15 Ratio	0	
Sorbent Inject., grams/hr	0	10 <sup>F</sup>	25 <sup>F</sup>	T14 Rate	0	T15 Rate	0	T14 Rate	T15 Rate	T14 Rate	T15 Rate	0	
Flue Gas Flow Rate	132 scfm												
FG O <sub>2</sub> Conc. (vol. %, dry)	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Sampling													
Ontario Hydro	In, ESP <sub>out</sub> , FF <sub>out</sub>	In, FF <sub>out</sub>	In, FF <sub>out</sub>	In, FF <sub>out</sub>		In, FF <sub>out</sub>	In, FF <sub>out</sub>	In, FF <sub>out</sub>	In, FF <sub>out</sub>	In, FF <sub>out</sub>	In, FF <sub>out</sub>		In, FF <sub>out</sub>
CMM	Continuous inlet and outlet during day and outlet only at night.												

<sup>A</sup> Between runs, conditions will be returned to baseline based on CMM mercury measurements only.

<sup>B</sup> C1 = Luscar coal from Poplar.

<sup>C</sup> S1 = Luscar char, steam activated.

<sup>D</sup> S2 = NORIT FGD, lignite-based activated carbon.

<sup>E</sup> A.R. = as received.

<sup>F</sup> Actual sorbent flow rates to be determined based on percent removals from CMM data for tests T2 through T4. T2 flow = 50%, T3 flow = 70%, and T4 = 90% removal or 30,000:1 ratio, whichever comes first (same applies to tests T14 and T15 at removal targets of 70% and 90%, respectively).

Continued . . .

**Table 8 (continued)**

Test Period Week 3, July 8–12													
Test No.	T24	T25	T26	T27	T28	T29	T30	T31	T32	T33	T34	T35	T36
Test Duration, hr	Average 2 to 3 tests per 24 hours depending on conditions and CMM information/steady state.												
Coal	C1 <sup>A</sup>	C1	C1	C1	C1	C1	C1	C1	C1	C1	C1	C1	Contingency Test, Repeat, or Other
Hardware	ESP/FF	ESP/FF	ESP/FF Ryton	ESP/FF Ryton	ESP	ESP	ESP	AHPC	AHPC	AHPC	FF	FF	
Temp., °F	300	300 <sup>B</sup>	300	300 <sup>B</sup>	300	300	300	300	300	300	300	300	
Sorbent	None	S1 <sup>C</sup>	None	S1	None	S1	S1	None	S1	S2 <sup>D</sup>	None	S1	
Sorbent Size	N.A.	A.R. <sup>E</sup>	N.A.	A.R.	N.A.	A.R.	Fine	N.A.	A.R.	A.R.	N.A.	A.R.	
Sorbent:Hg Ratio	0	Varied	0	T25 Ratios	0	T3 Ratio	T2 Ratio	0	T25 Ratio	T25 Ratio	0	T25/ Variable	
Sorbent Inject., grams/hr	0	Varied	0	T25 Rates	0	T3 Rate	T2 Rate	0	T25 Rate	T25 Rate	0	T25/ Variable	
Flue Gas Flow Rate	132 scfm												
FG O <sub>2</sub> Conc. (vol. %, dry)	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Sampling													
Ontario Hydro	In/Out	Out	None	Out	In/Out	Out	Out	In/Out	Out	Out	Out	Out	Out
CMM	Continuous inlet and outlet during day and outlet only at night.												

<sup>A</sup> C1 = Luscar coal from Poplar.<sup>B</sup> At the completion of testing, increase temperature gradually to 400°F (over a period of about 2 hrs) and monitor the CMMs.<sup>C</sup> S1 = Luscar char, steam activated.<sup>D</sup> S2 = NORIT FGD, lignite-based activated carbon.<sup>E</sup> A.R. = as received.

Continued . . .

**Table 8 (continued)**

Test Period Week 4, July 15–19													
Test No.	T36	T37	T38	T39	T40	T41	T42	T43	T44	T45	T46	T47	T48
Test Duration, hr	Average 2 to 3 tests per 24 hours depending on conditions and CMM information/steady state.												
Coal	C2 <sup>A</sup>	C2	C2	C2	C2	C2	C2	C2	C2	C2	Contingency Test, Repeat, or Other	Contingency Test, Repeat, or Other	Contingency Test, Repeat, or Other
Hardware	ESP/FF	ESP/FF	ESP/FF	ESP/FF	ESP	ESP	ESP	AHPC	AHPC	AHPC			
Temp., °F	300	300	300	300	300	300	300	300	300	300			
Sorbent	None	S1 <sup>B</sup>	None	S2 <sup>C</sup>	S1	S1	S1	None	S1	S2			
Sorbent Size	N.A.	A.R. <sup>D</sup>	N.A.	A.R.	None	Fine	A.R.	N.A.	A.R.	A.R.			
Sorbent:Hg Ratio	0	TBD	0	T37 Ratio	0	TBD	TBD	0	T37 Ratio	T37 Ratio			
Sorbent Inject., grams/hr	0	~40, TBD	0	T37 Rate	0	TBD	TBD	0	T37 Rate	T37 Rate			
Flue Gas Flow Rate	132 scfm												
FG O <sub>2</sub> Conc. (vol. %, dry)	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Sampling													
Ontario Hydro	In/Out	Out	In/Out	Out	In/Out	Out	Out	In/Out	Out	Out	Out	Out	Out
CMM	Continuous inlet and outlet during day and outlet only at night.												

<sup>A</sup> C2 = ND lignite, Freedom Mine.

<sup>B</sup> S1 = Luscar char, steam activated.

<sup>C</sup> S2 = NORIT FGD, lignite-based activated carbon.

<sup>D</sup> A.R. = as received.

**Table 9. Project Time Line**

Project Activity	Period of Activity	Percent Complete
Phase I	February 2002 – March 2003	40
Planning	February – August 2002	70
Bench-Scale Testing	April – September 2002	80
Pilot-Scale Testing	June – October 2002	30
Data Reduction/Reporting	June – February 2003	15
Phase II – Field Demonstration*	2003–2004	

\* Note: the Phase II timetable assumes 24 months are required for completion, but the actual schedule may be shorter (or longer), depending on Phase I results.